

TITLE OF THE INVENTION
Silicone Resin Composition for LED Devices

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BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to silicone resin compositions for light-emitting diode (LED) devices, and more particularly 10 to silicone resin compositions for the protection, bonding, wavelength alteration or adjustment, and lens formation in LED devices.

Background Art

In the prior art, epoxy resins are often used as the sealing material for LED devices. With respect to silicone resins, JP-A 10-228249 discloses the use as mounting members, JP-A 10-242513 corresponding to USP 5,998,925, USP 6,614,179, USP 6,069,440 and USP 6,608,332 discloses the use as lenses, 20 and JP-A 2000-123981 attempts to use silicone resins as wavelength adjusting coatings. Few silicone resins are actually used in such applications.

While a great focus is being directed to white LED, new problems emerge like UV-induced yellowing of epoxy resin encapsulants during actual use, which has been negligible, 25 and cracking of encapsulants by heat generation increased as a result of size reduction. It is urgently needed to overcome these problems.

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SUMMARY OF THE INVENTION

An object of the invention is to provide a silicone resin composition for use with light-emitting diode (LED) devices, that cures into a product which is fully transparent and is little discolored over time.

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The present invention provides a silicone resin composition of the addition reaction curing type comprising as essential components (A) a silicone resin having at least

two alkenyl groups bonded to silicon atoms in a molecule, (B) an organohydrogensilane and/or organohydrogenpolysiloxane having at least two hydrogen atoms bonded to silicon atoms in a molecule, and (C) an addition reaction catalyst.

5 One preferred embodiment of the invention is a silicone resin composition of the addition reaction curing type comprising as essential components,

(A) 100 parts by weight of a liquid or solid organopolysiloxane represented by the average compositional
10 formula (1):



wherein R is independently a substituted or unsubstituted
15 monovalent hydrocarbon group, alkoxy group or hydroxyl group,
0.1 to 80 mol% of the entire R groups being alkenyl groups,
and n is a positive number of $1 \leq n < 2$, and having a
viscosity of at least 10 mPa·s at 25°C,

(B) 2 to 100 parts by weight of an
20 organohydrogenpolysiloxane having at least two SiH bonds in a
molecule represented by the average compositional formula
(2):



25 wherein R' is independently a substituted or unsubstituted, monovalent hydrocarbon group excluding an aliphatic unsaturated hydrocarbon group, "a" is a positive number of 0.7 to 2.1, "b" is a positive number of 0.001 to 1.0, satisfying $0.8 \leq a+b \leq 2.6$, and having a viscosity of up to 1,000 mPa·s at 25°C and/or an organohydrogensilane represented by the formula: $R'_cSiH_{(4-c)}$, wherein R' is as defined above and c is 1 or 2, and

(C) a catalytic amount of an addition reaction
35 catalyst.

This silicone resin composition cures into a transparent product having heat resistance and discoloration resistance and is best suited for use with LED devices.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The silicone resin composition for LED devices of the present invention includes as essential components,

- (A) a silicone resin having at least two alkenyl groups bonded to silicon atoms in a molecule,
5 (B) an organohydrogensilane and/or organohydrogenpolysiloxane having at least two hydrogen atoms bonded to silicon atoms in a molecule, and
10 (C) an addition reaction catalyst.
10 For actual in-line use, a silicone resin composition of the heat curing type is preferred because it can be cured within a brief time.

The silicone resin (A) is preferably a liquid or solid organopolysiloxane of branched or three-dimensional network structure having a viscosity of at least 10 mPa·s at 25°C, represented by the average compositional formula (1).



20 Herein R is independently a substituted or unsubstituted monovalent hydrocarbon group, alkoxy group or hydroxyl group, 0.1 to 80 mol% of the entire R groups being alkenyl groups, and n is a positive number of $1 \leq n < 2$, preferably $1 \leq n \leq 1.8$, more preferably $1 \leq n \leq 1.5$.

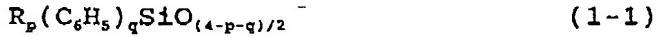
25 In formula (1), the silicon atom-bonded, substituted or unsubstituted, monovalent hydrocarbon groups represented by R are generally those of 1 to about 12 carbon atoms, preferably 1 to about 8 carbon atoms, for example, alkyl groups such as methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, pentyl, neopentyl, hexyl, cyclohexyl, octyl, nonyl and decyl, aryl groups such as phenyl, tolyl, xylyl and naphthyl, aralkyl groups such as benzyl, phenylethyl, and phenylpropyl, alkenyl groups such as vinyl, allyl, propenyl, isopropenyl, butenyl, hexenyl, cyclohexenyl, and octenyl, substituted ones of the foregoing groups in which some or all of the hydrogen atoms are substituted with halogen atoms (e.g., fluoro, bromo, chloro), cyano groups or the like, such as halo-substituted alkyl groups like

chloromethyl, chloropropyl, bromoethyl and trifluoropropyl, and cyanoethyl.

At least two of R groups must be alkenyl groups, preferably of 2 to 8 carbon atoms, more preferably 2 to 6 carbon atoms. The content of alkenyl groups is about 0.1 to 5 mol%, preferably about 0.5 to 50 mol%, more preferably about 1 to 30 mol% of the entire organic groups R (substituted or unsubstituted monovalent hydrocarbon groups).

Of the above-described silicone resins as component 10 (A), a silicone resin having a high phenyl content is more preferred because the incorporation of phenyl groups in the resin is effective to provide a high refractive index. The more preferred silicone resin has the average compositional formula (1-1).

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Herein R is as defined above, and p and q are positive numbers satisfying $1 \leq p+q < 2$, preferably $1 \leq p+q \leq 1.8$, 20 more preferably $1 \leq p+q \leq 1.5$, and $0.20 \leq q/(p+q) \leq 0.95$, preferably $0.30 \leq q/(p+q) \leq 0.80$, more preferably $0.45 \leq q/(p+q) \leq 0.70$. Reference is made to JP-A 11-1619.

The silicone resin used as the base polymer is preferably a liquid or solid organopolysiloxane having a viscosity at 25°C of at least 10 mPa·s, more preferably at 25 least 100 mPa·s, even more preferably at least 10,000 mPa·s. In component (A), a straight chain diorganopolysiloxane which contains alkenyl groups (e.g., vinyl) bonded to silicon atoms at ends of the molecular chain, silicon atoms midway the 30 molecular chain, or silicon atoms at ends of and midway the molecular chain, whose backbone consists essentially of recurring diorganosiloxane units, which is capped with triorganosiloxy groups at both ends of the molecular chain, and which may or may not contain phenyl groups may be blended 35 as an optional component for the purposes of adjusting the viscosity of the composition or the hardness of the cured product and so on.

Component (B) is an organohydrogensilane and/or an organohydrogenpolysiloxane, which serves as a crosslinking agent for causing the composition to cure, by inducing hydrosilylation reaction with the alkenyl group-containing silicone resin (A). Component (B) is desirably an organohydrogenpolysiloxane having at least two, especially at least three SiH bonds in a molecule represented by the average compositional formula (2):



wherein R' is independently selected from substituted or unsubstituted monovalent hydrocarbon groups excluding aliphatic unsaturated hydrocarbon groups, "a" and "b" are positive numbers satisfying $0.7 \leq a \leq 2.1$, $0.001 \leq b \leq 1.0$, and $0.8 \leq a+b \leq 2.6$, preferably $0.8 \leq a \leq 2$, $0.01 \leq b \leq 1$, and $1 \leq a+b \leq 2.4$, and having a viscosity of up to 1,000 mPa·s at 25°C and/or an organohydrogensilane represented by the formula: $R'_cSiH_{(4-c)}$, wherein R' is as defined above and c is equal to 1 or 2.

Examples of the monovalent hydrocarbon groups represented by R' are as exemplified for R in formula (1), with those free of aliphatic unsaturation being preferred.

Typical examples of the organohydrogensilane and organohydrogenpolysiloxane include $(\text{CH}_3)_3\text{SiH}_3$, $(\text{CH}_3)_2\text{SiH}_2$, $(\text{C}_6\text{H}_5)\text{SiH}_3$, 1,1,3,3-tetramethylcyclotetrasiloxane, 1,3,5,7-tetramethylcyclotetrasiloxane, both end trimethylsiloxy-capped methylhydrogenpolysiloxane, both end trimethylsiloxy-capped dimethylsiloxane-methylhydrogensiloxane copolymers, both end dimethylhydrogensiloxy-capped dimethylpolysiloxane, both end dimethylhydrogensiloxy-capped dimethylsiloxane-methylhydrogensiloxane copolymers, both end trimethylsiloxy-capped methylhydrogensiloxane-diphenylsiloxane copolymers, both end trimethylsiloxy-capped methylhydrogensiloxane-diphenylsiloxane-dimethylsiloxane copolymers,

copolymers consisting of $(CH_3)_2HSiO_{1/2}$ units and $SiO_{4/2}$ units, and copolymers consisting of $(CH_3)_2HSiO_{1/2}$ units, $SiO_{4/2}$ units and $(C_6H_5)SiO_{3/2}$ units.

The molecular structure of the
5 organohydrogenpolysiloxane may be a straight, branched, cyclic or three-dimensional network structure. The number of silicon atoms per molecule, i.e., degree of polymerization is preferably in the range of about 3 to about 1,000, more preferably about 3 to about 300.

10 Preferably the organohydrogenpolysiloxane has a viscosity at 25°C of up to 1,000 mPa·s, more preferably 0.1 to 500 mPa·s, even more preferably 0.5 to 300 mPa·s.

It is preferable that when the silicone resin (A) has a phenyl group, the organohydrogensilane and/or
15 organohydrogenpolysiloxane as component (B) has a phenyl group as well because this ensures transparency and prevents separation during shelf storage. In this embodiment, it is preferable that at least 5 mol%, more preferably 8 to 50 mol%, even more preferably 10 to 30 mol% of the entire groups
20 bonded to silicon atoms (R' and hydrogen atoms) in formula (2) be phenyl groups. Also preferably, component (B) is a mixture of an organohydrogenpolysiloxane of formula (2) wherein less than 15 mol%, especially 10 mol% to less than 15 mol% of the entire groups bonded to silicon atoms (R' and
25 hydrogen atoms) are phenyl groups and an organohydrogenpolysiloxane of the compositional formula (2) wherein at least 15 mol%, especially 15 mol% to 50 mol% of the entire groups bonded to silicon atoms (R' and hydrogen atoms) are phenyl groups in a weight ratio between 1:9 and
30 9:1, especially 3:7 and 7:3.

An appropriate amount of the organohydrogensilane and/or organohydrogenpolysiloxane blended as component (B) is 2 to 100 parts by weight, preferably 10 to 100 parts by weight per 100 parts by weight of the silicone resin (A).

35 Also, the organohydrogensilane and/or organohydrogenpolysiloxane as component (B) is used in such amounts that the molar ratio of silicon atom-bonded hydrogen

atoms (i.e., SiH groups) in component (B) to silicon atom-bonded alkenyl groups in the silicone resin or the silicone resin and the optional alkenyl group-containing straight chain diorganopolysiloxane combined as component (A) 5 may fall in the range of 0.5 to 5 mol/mol, preferably 0.8 to 4 mol/mol, and more preferably 1 to 3 mol/mol.

Component (C) is an addition reaction catalyst for promoting the hydrosilylating addition reaction between alkenyl groups in component (A) and SiH groups in component 10 (B). Typical addition reaction catalysts are platinum group metal catalysts including platinum catalysts such as platinum black, platinum chloride, chloroplatinic acid, the reaction products of chloroplatinic acid with monohydric alcohols, complexes of chloroplatinic acid with olefins, and platinum 15 bisacetoacetate, palladium catalysts, and rhodium catalysts. The addition reaction catalyst may be used in a catalytic amount, preferably in such an amount to give about 1 to 500 ppm, especially about 2 to 100 ppm of platinum group metal based on the weight of components (A) and (B) combined.

20 In addition to components (A) to (C) described above, the inventive composition may further comprise optional components insofar as the objects of the invention are not compromised. Suitable optional components include addition reaction inhibitors for adjusting cure and imparting a pot life, and hardness or viscosity-adjusting agents, for example, non-reactive straight chain organopolysiloxanes and straight chain or cyclic low-molecular-weight organopolysiloxanes having about 2 to about 10 silicon atoms as well as the above-described alkenyl group-containing 25 straight chain diorganopolysiloxane which may or may not contain a phenyl group, such as dimethylpolysiloxane.

Insofar as transparency is not impaired, there may be blended inorganic fillers such as fumed silica for enhancing strength. If desired, wavelength adjusting agents, dyes, 30 pigments, flame retardants, heat resistance improvers and antidegradants may also be blended.

The composition may be cured under any desired conditions although it is preferably cured by heating at about 120 to 180°C for about 30 to 180 minutes.

The silicone resin compositions of the invention are used with LED devices for the purposes of protection, encapsulation, bonding, wavelength alteration or adjustment, and lens formation of LED devices and afford transparent cured products having heat resistance and discoloration resistance.

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EXAMPLE

Examples of the invention are given below by way of illustration and not by way of limitation.

15 Example 1

A reactor was charged with toluene, ethyl polysilicate, vinyldimethylchlorosilane, and trimethylchlorosilane. Co-hydrolytic polymerization was effected, yielding a 50 wt% toluene solution of an organopolysiloxane resin copolymer (silicone resin) consisting of $\text{CH}_2=\text{CH}(\text{CH}_3)_2\text{SiO}_{1/2}$ units, $(\text{CH}_3)_2\text{SiO}_{1/2}$ units and SiO_2 units, and having a ratio of [$(\text{CH}_3)_2\text{SiO}_{1/2}$ units + $\text{CH}_2=\text{CH}(\text{CH}_3)_2\text{SiO}_{1/2}$ units]/ SiO_2 units equal to 0.85 mol/mol and a vinyl group content of 0.02 mol/100 g. This was combined with an equal amount calculated as solids of a vinyl end-capped dimethylpolysiloxane having a viscosity of 500 mPa·s at 23°C. The mixture was vacuum stripped at 150°C until the depletion of strippable matter, yielding a liquid material having a viscosity of 30,000 mPa·s. To 100 parts by weight of this silicone resin as the base were added an amount of a platinum catalyst to give 20 ppm platinum element and 0.5 part by weight of tetravinyltetramethyltetracyclosiloxane as a reaction inhibitor. To 100 parts by weight of this mixture was added 6 parts by weight of methylhydrogensiloxane capable of generating 350 ml/g of hydrogen gas and having a viscosity of 20 mPa·s at 23°C as a curing agent. They were mixed and deaerated, after which the

composition was cast into a glass plate-assembled mold to a thickness of 3 mm where it was cured at 120°C for one hour.

Example 2

5 A reactor was charged with toluene, phenyltrichlorosilane, vinylmethyldichlorosilane, and dimethyldichlorosilane. Co-hydrolytic polymerization was effected, yielding a 50 wt% toluene solution of an organopolysiloxane resin copolymer (silicone resin) consisting of $(C_6H_5)SiO_{3/2}$ units, $(CH_2=CH)(CH_3)SiO_{2/2}$ units and $(CH_3)_2SiO_{2/2}$ units, and having an average compositional formula: $(CH_3)_{0.65}(C_6H_5)_{0.35}(CH_2=CH)_{0.25}SiO_{1.25}$. To 100 parts by weight of this silicone resin dissolved was added 10 parts by weight of a phenylmethylhydrogensiloxane containing 20 mol% of phenyl groups based on the total of silicon atom-bonded methyl groups, phenyl groups and hydrogen atoms (SiH groups), capable of generating 150 ml/g of hydrogen gas and having a viscosity of 10 mPa·s. After mixing, the mixture was vacuum stripped at 150°C until the depletion of strippable matter.

10 15 20 25 The mixture was cooled to room temperature, after which 0.2 part by weight of ethynyl cyclohexanol as a reaction inhibitor was added. To the mixture was added an amount of a platinum catalyst to give 20 ppm platinum element. They were mixed by agitation and deaerated, after which the composition was cast into a mold as in Example 1 where it was cured at 120°C for 30 minutes. The cured product was taken out of the mold and post-cured in a drier at 180°C for 2 hours, obtaining a sample.

30 Example 3

A reactor was charged with toluene, phenyltrichlorosilane, vinylmethyldichlorosilane, and dimethyldichlorosilane. Co-hydrolytic polymerization was effected, yielding a 50 wt% toluene solution of an organopolysiloxane resin copolymer (silicone resin) consisting of $(C_6H_5)SiO_{3/2}$ units, $(CH_2=CH)(CH_3)SiO_{2/2}$ units and $(CH_3)_2SiO_{2/2}$ units, and having an average compositional

formula: $(CH_3)_{0.65}(C_6H_5)_{0.55}(CH_2=CH)_{0.25}SiO_{1.28}$. To 100 parts by weight of this silicone resin dissolved were added 20 parts by weight of a phenylmethylhydrogensiloxane containing 20 mol% of phenyl groups based on the total of silicon atom-bonded methyl groups, phenyl groups and hydrogen atoms (SiH groups), capable of generating 150 ml/g of hydrogen gas and having a viscosity of 10 mPa·s and 10 parts by weight of a phenylmethylhydrogensiloxane containing 10 mol% of phenyl groups based on the total of silicon atom-bonded methyl groups, phenyl groups and hydrogen atoms (SiH groups), capable of generating 120 ml/g of hydrogen gas and having a viscosity of 20 mPa·s. After mixing, the mixture was vacuum stripped at 150°C until the depletion of strippable matter. The mixture was cooled to room temperature, after which 0.2 part by weight of ethynyl cyclohexanol as a reaction inhibitor was added. To the mixture was added an amount of a platinum catalyst to give 20 ppm platinum element. They were mixed by agitation and deaerated, after which the composition was cast into a mold as in Example 1 where it was cured at 120°C for 30 minutes. The cured product was taken out of the mold and post-cured in a drier at 180°C for 2 hours, obtaining a sample.

Comparative Example

A commercially available transparent epoxy resin material commonly used with lamp type LEDs was cast into a mold as in Example 1 and cured at 150°C for 8 hours, obtaining a sample.

Physical properties of the samples of Examples and Comparative Example are shown in Table 1.

Table 1

Properties	Example 1	Example 2	Example 3	Comparative Example
Refractive index of base	1.41	1.51	1.51	1.51
Hardness (Shore D)		75	74	85
Hardness (Shore A)	77			
Flexural strength* (MPa)		100	95	135
Tensile strength** (MPa)	5.4			

* JIS K 6911

** JIS K 6249

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The samples of Examples and Comparative Example were examined for light transmittance by the following tests.

A sample as prepared was measured for light transmittance at 400 nm, obtaining an initial value. The 10 sample was exposed to ultraviolet radiation in a sunshine weatherometer (Suga Tester Co., Ltd.) for 100 hours and 500 hours, after which light transmittance was measured again. The results are shown in Table 2.

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Table 2

Light transmittance	Example 1	Example 2	Example 3	Comparative Example
Initial	95	95	94	97
After 100 hour exposure	91	93	92	81
After 500 hour exposure	92	91	90	65

Separately, a sample as prepared was held in a drier at 120°C for 100 hours and 500 hours, after which light 20 transmittance was measured again. The results are shown in Table 3.

Table 3

Light transmittance	Example 1	Example 2	Example 3	Comparative Example
Initial	95	95	94	97
After 100 hour heating	92	90	92	78
After 500 hour heating	92	88	90	65

5 Japanese Patent Application No. 2002-347603 is
incorporated herein by reference.

Although some preferred embodiments have been
described, many modifications and variations may be made
thereto in light of the above teachings. It is therefore to
10 be understood that the invention may be practiced otherwise
than as specifically described without departing from the
scope of the appended claims.